LUBRICATION

Published by THE TEXAS COMPANY
17 Battery Place, New York City

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VOL. V MAY, 1918 No. 7

Published Monthly in the interest of efficient lubrication.

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EDITORIALS.

Now that the Third Liberty Loan campaign has been happily completed, every American should again turn his attention to Thrift Stamps and War Saving Stamps as one very important means of helping to win the war. When one stops to consider the sacrifices that thousands of Americans are making in this war he should be impelled to leave no stone unturned to do a little more than his "bit." War Saving Stamps offer an excellent opportunity to help finance the war, to encourage habits of thrift, and at the same time to secure the safest investment in the world, redeemable with interest at any time. Lend your quarters to Uncle Sam!

The requirements of our Navy, of our War Machine, and of our Allies have increased enormously the demands for lubricating oil, and at the same time there is a correspondingly increased demand throughout the industrial world. In spite of all efforts of the oil producers and refiners the production of crude petroleum and of finished products is below normal. This is due in part to the scarcity and prohibitive cost of drilling apparatus and partly to the scarcity of labor. The difficulties of transportation, both by rail and by water, make the problem an even more serious one. If the industrial world is to avoid a serious tie-up because of the lack of lubricants there must be a more complete co-operation between the consumers of oil and the oil companies. Oil must be used so as to secure the greatest amount of efficiency, and waste must be reduced to a minimum. One purpose of this month's article on Steam Cylinder Lubrication is to point out how steam cylinders may be lubricated efficiently and with the greatest possible economy in the use of steam cylinder oil.

Steam turbines should be lubricated with a minimum amount of high grade lubricating oil. The operation of a turbine with an oiling system in which the oil is constantly circulated without purification until it is necessary to clean out the system and throw away the oil, or perhaps partially filter it and use it for some rough work, is a waste which should not be tolerated at the present time when efficiency and economy are the watchwords. The article on Steam Turbine Oil Filtration explains two methods by which steam turbine oil may be constantly filtered, purified, and returned to the system, thus rendering the oil serviceable for an indefinite period.

STEAM CYLINDER LUBRICATION

By W. F. Osborne

IN 1914 the United States Census Bureau reported a total of 137,176 steam engines operating in the United States having a total rated horsepower of 15,681,688. Since that time the number of steam engines in use has been considerably increased, with a correspondingly increased demand for steam cylinder oils. As lubricating oils for steam cylinders are almost exclusively petroleum products, this increased demand has fallen on the petroleum industry, and while the production of petroleum has been greatly intensified, it is nevertheless quite necessary that all oils be conserved as much as possible to meet the requirements of the war industries of the United States and her Allies. Steam cylinder oils may be conserved by the engineer thru the application of scientific principles to the selection and use of the oil most suitable for each case. With the possible exception of internal combustion engines, the steam engine is the most familiar form of power producing machinery, and a short discussion of the principles involved will, perhaps, be of some interest and assistance to operating and designing engineers.

The sliding of the piston and piston rings over the internal surface of the cylinder wall creates a certain amount of friction, which, if not reduced by the use of some lubricating substance, will cause the loss of a considerable amount of power, and at the same time, will rapidly wear out the cylinder, piston and rings. It is therefore necessary to form a lubricating film on the cylinder walls and the rubbing portion of the piston and piston rings, which will prevent this excessive friction. Practically all forms of steam engines, steam pumps and steam cylinder operated apparatus are equipped with valves for controlling the action of the steam, and the majority of these devices also requires lubrication to prevent wear and to reduce friction.

The loss of power caused by an improperly lubricated cylinder can be shown very readily on the indicator card by fixing all other conditions of operation and varying only the degree of cylinder lubrication. A poorly lubricated cylinder will quickly show on the card thru increased i. h. p. or card area, and this increased steam consumption, of course, entails a greater coal consumption.

An English authority has estimated that if all the poor grades of oils in use were replaced with good oils, a saving of 15% could be made in the amount of coal used for power purposes. This seems like a big figure but it should be understood that this excessive loss is not due to the actual difference in the coefficient of friction of good and poor oils, but rather to the wear and destruction of machine parts thru the inefficient or incomplete lubricating film provided by poor or unsuitable oils. This wearing of bearings and cylinders increases the friction and likewise the amount of coal necessary to develop the desired amount of power.

There are two ways of handling this problem of lubricating steam cylinders. One method is to take the engine as it stands, with all accessories ready for service, and after considering all of the influencing factors, select the oil which will best meet the existing conditions. Some-

times it is possible to make changes in the installation, favoring the use of an oil that will give better cylinder lubrication than could be secured from another oil selected to meet the existing mechanical conditions.

The other method is to consider the principles of efficient lubrication when the engine and its accessories are designed, built and installed. There is no question but that better lubricating service can be secured at a lower cost for oil and less expense on account of lost power and repairs, if the latter course is adopted. This, of course, requires an expert knowledge of operating conditions and lubricating oils, and entails very close co-operation between the engine builder and the oil manufacturer.

Considering first the design of the engine, the features which influence the method of lubrication and the kind of oil which may be used are the cylinder, the valves, the steam flow and the degree of steam expansion.

Vertical cylinders are comparatively simple to lubricate as the weight of the piston and rings, piston rod, cross head and connecting rod are carried by the crank pin. The only pressures on the cylinder walls are those due to the tension of the piston rings and possibly to some slight pressure from any side motion which the piston may have. The rings, no matter of what design, should be set out only tightly enough to prevent steam leakage. A film of oil thick enough to prevent excessive friction between these rings and the cylinder walls, and enough oil to maintain this film, are all that is required to provide proper lubrication. The selection of oil is based on the same principles that govern the oil used for horizontal cylinders and the quantity required is very small.

For salt water marine engines where the condensed steam is used for boiler feed, because of the lack of efficient oil separators, the common practice is to run these vertical cylinders without any oil at all and to depend entirely upon the amount of water present in the steam to afford lubrication. The space rings and piston usually have water grooves to hold a small amount of condensed steam which serves to decrease steam leakage, making it possible to use looser fitting rings and consequently decreasing the friction. After a short time, these cylinder walls become highly polished and glazed, so that the actual friction is lessened.

In the horizontal cylinder, except where tail rods are used, the weight of the piston rings and part of the weight of the piston rod must be borne by the lower portion of the cylinder. On account of this weight the piston tends to wear the bottom of the cylinder out of round, and unless sufficient lubrication is provided, the clearance between the piston and the cylinder may become so great as to cause serious leakage of the steam past the piston. This steam increases the pressure to which the oil film is subjected, and may weaken or entirely destroy it. If the rings become worn and sharp on the edges they will scrape the oil film off the surface of the cylinder walls, further increasing friction and wear. Because of these conditions the cylinder oil must have the characteristics which will provide a heavy film of oil and must be used in sufficient quantities to maintain it. Even with the most efficient oil a certain amount of wear will take place and the rings will have to be renewed occasionally.

Engines having heavy pistons and rods are usually provided with tail rod supports which, together

with the cross head, carry the weight of the piston and rods. In such engines the only pressure on the cylinder walls is that carried by the tension of the piston rings, and a thinner film of oil and a lesser quantity of lubricant are required.

The various types of valve gear in common use for controlling the operation of steam engines may be classified as, piston valves, slide valves, Corliss valves and poppet valves. Piston valves or any other form of completely balanced valves are comparatively easy to lubricate as there is no pressure on the valve seat, except the weight of the valve, and a small amount of oil will afford satisfactory lubrication. Slide valves, unbalanced, or only partially balanced, however, require careful and efficient lubrication, as the sliding action of the valve on its seat, under the pressure of the steam, tends to wipe the oil film off very quickly. Improper lubrication will result in cut or worn valves and seats, and is readily detected by a jerky motion of the valve stem caused by the valve's sticking to the seat momentarily.

Corliss valves are usually the hardest to lubricate because they are held tightly against the seats by the pressure of the steam. The ends of these valves also have to be lubricated and unless they are designed with particular attention to their lubrication, some trouble may be experienced. It is frequently necessary to run a special oil feed pipe direct to each inlet valve, and sometimes a feed to each end is required. Poppet valves have no moving parts to be lubricated except the valve stems, and this is usually very simple.

Steam engines may also be classed according to the way in which the steam flows thru the cylinder. The contra-flow engine is the ordinary type in which steam is admitted and exhausted from the same end of the cylinder. The exhaust steam, being much cooler than the incoming steam, lowers the temperature of the valves and the walls near the end of the cylinder, thus increasing the amount of condensation. This condensation of steam has a great effect on the oil, as will be explained later. The uniflow engine is so designed that the steam flows in one direction only, being admitted at the end and exhausted at the center of the cylinder. These cylinders are very long and on account of low temperatures at the center and the constant washing effect of the wet steam at the exhaust ports, require oil somewhat different from the usual type of engine. The piston is necessarily very long and has a much greater area needing lubrication.

The above statements apply to engines having one or more cylinders, but because of the peculiar operating conditions involved and their effect on the cylinder oil, the compound engine is made the subject of a later paragraph.

The methods of applying the oil to the cylinder and valves may now be given consideration. These methods, it should be realized, are necessarily quite different from those employed in lubricating the internal surfaces of cylinders of internal combustion engines, air compressors, etc. The oil is usually applied in one of two ways. It is either fed directly to the cylinder walls or it is carried in by the steam. The degree of lubrication effected and the economy in the use of the oil depend entirely upon the successful covering of the moving parts with a film of oil.

Oil introduced into the cylinder either runs only a short distance down the side of the cylinder before

it is swept toward the end of the cylinder by the piston, or drops toward the bottom of the cylinder where it is wiped to the counterbore at the end of the cylinder without having an opportunity to lubricate anything except a small strip in the bottom. The chances are very great that a falling drop of oil would never strike any part of the cylinder but would be carried out thru the exhaust by the steam. This oil, of course, will lubricate the exhaust valves, but where separate inlet valves are used an additional oil feed must be provided to take care of their lubrication. It should be realized that, while it is entirely possible to lubricate cylinders in this manner—and this method is frequently used—a great deal of oil is necessarily put into the cylinder that has no chance at all of lubricating anything. In fact, when the exhaust steam is used for manufacturing processes and for boiler feed water, considerable damage may be done by the use of such large quantities of oil, unless an extremely efficient oil separator is installed in the exhaust line.

The most efficient way of getting the lubricating oil to all desired points is to make use of the steam itself, which reaches all moving parts inside of the valve chambers and cylinders with the possible exception of parts of certain types of Corliss valves. If the oil is divided into minute globules and intimately mixed with the steam, only a very small quantity is required, and the degree of success in the atomization of the oil will control both the efficiency of lubrication of the parts and the quantity necessary. The more complete the atomization and the more thoroly saturated all portions of the steam, the better will be the lubrication of all of the cylinder parts, and the more economical will be the consumption of oil.

The degree of atomization of the oil is influenced by the condition of the steam, the point of introduction of the oil, the velocity of the steam, and the character of the oil itself. Other things being equal, a high steam pressure will produce quicker atomization of a given oil than a low steam pressure, due to the high temperature thinning down the oil to a greater extent, so that a comparatively heavy bodied oil may be atomized by a high pressure steam as quickly as a light bodied oil will be atomized by a low pressure steam. Conversely, a low pressure steam requires a light bodied oil in order to secure efficient atomization.

The degree of atomization is also affected by the point of introduction of the oil into the steam, in that the farther the point of introduction is from the cylinder, the greater will be the opportunity for complete atomization. If the oil is introduced directly into the valve chest or just above the throttle, an oil must be used which will break up very quickly. On the other hand, if the point of introduction is from six to eight feet from the cylinder, it is possible to use a slower acting oil if other conditions render it necessary or advisable. Further, if it is found necessary to use a heavy bodied oil to meet the cylinder conditions, better lubrication may be secured at a more economical cost by placing the introduction of the oil further back from the cylinder. There is a limit, however, to the distance practical, as if the oil is put into the steam too far from the cylinder, too much condensation of oil on the sides of the steam pipe will occur, and result in a greater oil consumption, as the oil will run

down into the steam chest without vaporizing.

Cylinder oils have certain inherent characteristics in regard to their ability to atomize which, in general, are as follows: A light bodied oil will atomize more quickly than an unfiltered oil. A cylinder oil compounded with animal oils has a greater tendency to atomize than the same cylinder stock without the compounding.

Atomization of the oil is usually accomplished by introducing it into the steam line thru a small pipe, spoon shaped at the open end, extending to about the center of the steam line. Care should be taken to place the introduction pipe so that there are as few bends between it and the cylinder as possible, as the steam striking the pipe at the bend throws out some of the oil onto the pipe where it sticks and runs down the side. If a steam separator is installed the oil should always be fed between the separator and the engine, otherwise the separator will remove a considerable part of the oil. Better atomization of any oil can be secured by feeding very small drops at frequent intervals than by feeding large drops at long intervals.

Practical experience and many tests have demonstrated the soundness of the atomization theory, and the fact that the most efficient results can be secured in this way. While, of course, a considerable amount of oil which is carried by the steam never comes in contact with the metal surfaces, nevertheless, it has been clearly shown that far less oil is wasted when the oil is completely atomized than when it is introduced directly into the cylinder or valves. The primary consideration is, of course, the efficient lubrication of the cylinders, and the oil should be selected with this in view. Then if the point of introduction is not right to handle the oil selected and if the mechanical conditions will permit, the point of introduction of the oil should be changed to secure proper atomization of the oil. Many times, however, it is not feasible to locate the introduction pipe at the correct point, and it becomes necessary to compromise by changing the character of the oil or by increasing the amount used.

After the point of introduction has been determined and the lubricating oil selected, attention should be given to the means provided for getting the oil to the desired point. This is accomplished by the use of one of the many types of lubricators which may be generally classified as hydrostatic and mechanical. Both are, of course, familiar to all operating engineers and their principles of operation need not be explained. It might be well, however, to discuss some of the troubles sometimes arising, and the difference in the action of the lubricators in relation to complete atomization of the oil.

Hydrostatic lubricators provide an intermittent flow of oil, that is the oil feeds into the steam line at intervals depending on the adjustment of the regulating valve and the viscosity of the oil. A heavy bodied oil will flow thru the sight glass slowly in large drops, while a lighter bodied oil will feed in smaller drops at more frequent intervals, the latter condition giving the more uniform and more complete saturation of the steam.

Complaints are sometimes made that the oil will not feed properly, that it runs up the side of the glass, discoloring it and rendering it impossible to observe the feed. This is frequently caused by the use of a steam gauge glass formerly used. If it is not possible to get a proper

glass, the size of the drop may be reduced by filing down the lip on the feed valve and soldering a fine wire to the lip to allow the oil to follow the wire. If the oil backs up in the sight feed glass, it is usually due to lack of enough difference in the pressure on the sides of the lubricator and may be improved by increasing the distance between the two connections into the steam pipe.

Mechanical lubricators are made of two types, one of which delivers a quantity of oil at intervals, which may be regulated by adjusting the length of the plunger stroke or the time required to complete a stroke. Lubricators of this type, feeding quantities of oil at comparatively long intervals, do not give the oil a chance to saturate all portions of the steam or to completely atomize before it reaches the cylinder. The other type of lubricator feeds a very small amount of oil into the steam line at every revolution of the engine, thus providing constant feed and affording a better opportunity for complete atomization and saturation of the steam. Frequently engines are exposed to very low temperatures and unless some provision is made to keep the oil in the reservoir warmed up, it becomes thick and will not flow thru the sight feeds to the plungers.

Certain types of lubricators are unsuitable for compound condensing engines operating with a pressure below atmosphere in the low pressure cylinder, unless the check valves on the discharge side of the lubricator are spring loaded, as the low pressure may cause the oil to be drawn out of the reservoir into the cylinder in large quantities with great waste.

The condition of the steam should always be thoroly investigated before selection of a cylinder oil is made and the pressure, degree of superheat, percentage of moisture, condition of the boiler water and the general layout of pipe lines and separators carefully considered. The pressure of the steam affects the oil insofar as the temperature of the steam varies with the pressure. The temperatures of steam at different gauge pressures are given in the table below:

STEAM TEMPERATURES
(Marks & Davis)

Inches Vacuum	Temp. Fahr.
28.	101.
26.	125.
24.	140.
Gauge Pressure	
0.	212.
25.	266.9
50.	297.
75.	320.1
100.	337.9
125.	352.9
150.	365.9
160.	370.7
175.	377.5
190.	383.9
200.	387.9

The highest temperature shown for steam at 200 lbs. gauge pressure is only 387.9° F., which is far below the open flash point of any cylinder oil, and as it is probable that the flash point would be raised with the increased pressure, there does not seem to be any reason for the common belief that a very high flash or fire test is necessary. Saturated steam always contains moisture and as there is very little free oxygen present in the steam it does not seem likely that a flash could be produced in the cylinder regardless of the flash point of the oil. As long as the oil has the proper body or viscosity, a characteristic which is not influenced by the flash test, and has the ability to break up quickly, it does not seem necessary to consider this point. The temperature of the steam, however, does affect the

oil to be used, in that the higher the temperature the thinner will be the oil and the more quickly will it be atomized. Conversely, where steam pressures are low, or where a partial vacuum with accompanying low temperatures, as shown by the above table, exists as in condensing engines, a very easily atomized oil is necessary.

Practically all steam from the steam generating drums or tubes of a boiler contains a percentage of moisture and unless subsequently superheated, will reach the cylinder in a wet condition. Moisture in the steam has the effect of washing the oil off the valves and cylinders, decreasing or completely destroying the lubricating film. To offset this destructive action of water the oil must have certain characteristics, such as a greater natural adhesiveness, or must contain some material which will provide lubrication after the water has washed off the oil. To meet these conditions a certain amount of animal oil is added to the cylinder oil, which upon coming in contact with water saponifies and lubricates the cylinders. The percentage of animal oil required depends upon the amount of water present but usually ranges from 3% to 12%.

Many boiler plants use water for boiler feed purposes which contains such quantities of mineral substances that very serious scale deposits would be formed in the boiler if the water were not treated. The boiler compounds ordinarily used contain soda ash or lime, both being strong alkalis. Comparatively dry steam carrying a low percentage of water from the boiler removes only a very small amount of the compound from the boiler, while the addition of freshly treated boiler water gradually increases the amount of compound present in the boiler until it reaches the point at which foaming or priming occurs. This, of course, causes large quantities of water highly saturated with the alkali to be carried along with the steam thru the lines to the engine. This water containing lime, magnesia, soda ash, silica, boiler scale, etc., has a very bad effect on the oil film covering the valves and cylinder walls, and where such conditions exist it is necessary to use large quantities of highly compounded oil, specially manufactured to resist this destructive action. Sometimes an examination of the cylinder will show no indication of oil at all and the surfaces will be rough and, frequently, rusty if the engine has been standing a short time.

Constant and careful attention should be given to the cause and prevention of such troubles wherever possible. Boiler foaming and priming may be reduced by more careful regulation of the introduction of boiler compound and by frequent blowing down of the boiler to prevent the salts from becoming sufficiently highly concentrated to cause priming. Boilers equipped with suitable dry pipes or steam domes have a less tendency to prime than where these are not provided. Some boilers where steam is taken from the center drum, may be greatly improved by changing the steam outlet to the rear drum and forcing the steam from the center to the rear drum. This will greatly decrease the amount of moisture in the steam and consequently improve the lubricating condition of the cylinder.

Separators of efficient design and ample capacity to remove the water carried by the steam from the boiler and the condensation in the steam pipes, placed near the engine, will improve the lubricating conditions in the cylinders even when serious

conditions prevail at the boiler plant. Sometimes engines are placed at the end of long steam lines which, altho covered with good insulating material, will, nevertheless, radiate heat sufficiently to permit of considerable condensation, and separators installed in the proper place to prevent this water reaching the cylinder will serve the purpose of saving the oil film from destruction, prevent the danger of the cylinder head being knocked out, and generally improve the efficiency of the engine.

In general unfiltered straight run steam refined cylinder oils, compounded with the proper percentage of animal oil form the best water resisting cylinder oils. Filtered cylinder oils have not the adhesiveness to enable them to stick to the cylinder walls properly under such severe conditions.

Having discussed the effect of moisture on the lubricating oils, we are now in position to take up the compound engine. The purpose of a compound engine consisting of two or more cylinders is to permit of a large steam expansion without excessive condensation. The high pressure cylinder presents practically the same lubricating conditions as that of any simple engine except that, in general, the exhaust pressure is higher and the cylinder dryer. Many times the cylinder and inlet valves of a simple engine will be perfectly lubricated but the exhaust valves will groan and stick because the condensed steam has washed off the oil. The steam from the high pressure cylinder passes into a receiver where a large part of the steam which has been previously condensed by the expansion process in the high pressure cylinder is removed thru traps. This water of condensation carries with it the liquid oil and the oil washed from the high pressure cylinder walls, together with any saponified oil. The steam then goes to the low pressure cylinder at a reduced pressure carrying with it the uncondensed atomized oil from the high pressure cylinder, which helps to lubricate the valves and cylinders, tho it is usually necessary to add more oil in the valve chest or the pipe coming from the receiver to give sufficient lubrication. Because the steam going to the low pressure cylinder is much cooler and usually much wetter than the high pressure steam, it is sometimes advisable to use an oil which will break up more quickly under the lower temperatures, especially where high economy is dedesired. This is particularly true where the receiver pressure is only a few pounds or even below atmospheric pressure. The more complete the atomization of the oil before it enters the high pressure cylinder the greater will be the benefit accruing to the low pressure cylinder and the more economical will be the oil consumption.

Among the conditions of operation which affect the quantity and character of the oil are the speed of the engine, the load variation and length of time the engine is run between shut downs. The speed of the engine primarily affects the quantity of oil necessary to lubricate the cylinders, and secondly affects the atomization of the oil thru the change in the velocity of the steam at the point of oil introduction. A steady uniform load seldom requires a change in the amount of oil fed or an adjustment of the lubricator and the supply may be reduced to a minimum with little danger of damage to the cylinder. A widely variable load, such as rolling steel, however, imposes very severe conditions on the lubricant, as a sudden draft of steam, frequently accompanied by water may find the cylin-

der wholly unprepared and it is always necessary to use enough oil to meet the extreme conditions which, of course, causes a considerable waste of oil on light loads. Compound condensing engines are particularly susceptible to lubricating difficulties in the low pressure cylinder and in the exhaust valves, where loads are variable. If the engine is shut down for a few hours at irregular periods, with a small amount of steam blowing thru the cylinders to keep them warm, it is usually advisable to pump some oil into the cylinder by hand, just before shutting down and again just before starting up, as the steam blowing thru the cylinder is likely to dry up all the oil deposited during the usual running time.

A well lubricated cylinder, upon examination, will present a highly polished surface, free from rough spots, and will vary in color from a light silver to a gun metal blue. The oil film at the top, bottom and sides should be thick enough to penetrate from three to six thicknesses of "Rizla" cigarette paper, which is suggested because of its uniform thickness. If the stain on the paper is not of a light brownish color, but is blackish or shows up dusty, it generally indicates that the oil is carbonizing or that the surfaces are not properly lubricated and are wearing. Sometimes it may be the cylinder which is being worn and again it may be the piston rings, but, in any event, a careful examination should be made to determine and remove the cause of the trouble. If bright streaks of a lighter color than the remainder of the cylinder appear, it is quite possible that the piston rings are scratching the cylinder or that some gritty substance, such as boiler scale, is getting into the cylinder. Care should be taken to examine the cylinder as soon as possible after the engine is shut down, as some cylinder oils have a tendency to quickly evaporate making it impossible to determine the quantity of oil appearing on the cylinder walls when the engine is actually in operation.

Deposits in the counter-bore, valve and other parts of the cylinder may be due to excessive oil consumption or to boiler scale and boiler compound, held together with a small amount of oil.

Lack of lubrication may be quickly observed when the engine is running by the groaning and sticking of the valves, and may be due to a great many things which should be carefully investigated and the cause removed. Sticking of Corliss Valves may be caused by a sudden shot of water washing the oil off and causing them to run dry. The valves may also stick from some defect of valve gear and dash pots, or because of a mechanical defect in the valve or seat.

In addition to lubricating the cylinder and valves of a steam engine, oil properly introduced into the steam and efficiently atomized will also lubricate the throttle valve stem and automatic safety shut-off valve, preventing rust and keeping the valves in good condition. The oil in the steam will also lubricate the piston and valve rods just as well as it lubricates the cylinder, and if the packing is properly put in and kept up, without being drawn up excessively tight, no additional oil need be fed on the rods outside of the stuffing box. It is sometimes necessary, however, to feed additional oil to prevent scoring of the rod, if the carbon packing is used, particularly when it rubs very tightly on the rod.

Special classes of steam cylinder lubrication require special lubricants, some of the most important

of these being marine engine, steam pumps, refrigerating plants and plants where the exhaust steam is used for boiler feed or manufacturing purposes.

Steamships on salt water invariably use the condensed steam for boiler water make-up and as it is essential to the safe working of the boilers that no oil gets in them, the cylinders are usually run without any oil at all being fed into them, depending solely upon the moisture in the steam lubrication. Oil is used, however, for swabbing the rods, and a small quantity naturally works into the cylinder. For this reason a pure mineral oil is used, as it may be removed from the steam by the use of proper oil separating devices.

Altho the same method is employed in lubricating steam pump cylinders as for steam engine cylinders, the operating conditions are somewhat different owing to the intermittent operation. Elevators, boiler feed, tank well pumps, etc., are usually controlled by an automatic regulator placed on the discharge side of the pump by which the speed of the pump is controlled. When the pump is shut down, the condensation which takes place in the steam line has a great tendency to wash the oil from the cylinder walls when the steam valve is opened by the regulator, and, on this account, the oil used must be of such a nature as to resist this washing action. Oils highly compounded with animal oil usually give the best results.

If the condensed steam from the engines is used for the manufacture of ice, great care should be taken that all oil is thoroly removed from the water. Oil in the water will cause a yellowish porous formation in the ice which is very objectionable, particularly where the ice is used for drinking water. While all such ice plants are equipped with an oil extractor, the majority of these devices are not capable of completely removing any oil except a pure mineral cylinder oil. It is therefore advisable not to use compounded cylinder oils unless absolutely necessary. Even mineral oils should be used in very small quantities. The same difficulty is experienced in plants where the exhaust steam comes in direct contact with the product or is used for boiler feed water, and it is usually necessary to use a straight mineral cylinder oil.

Many kinds of oils, greases and other substances have been placed on the market to meet the various lubricating requirements of steam cylinders. The oil most widely used prior to the present petroleum oils was tallow oil which was heated in a tallow pot on the top of the cylinder and poured in. With the improvement of petroleum oils, the use of tallow rapidly decreased, and is now practically unknown except in compound with petroleum oils. Petroleum cylinder oils of a high degree of perfection are now manufactured and are undoubtedly the most efficient and economical cylinder lubricants. As a point of interest and assistance to operating engineers it might be well to mention the Texaco cylinder oils recommended as suitable for the various classes of service outlined above.

High steam pressures, superheat, severe service, oil fed into steam line—Texaco 650-T Cylinder Oil.

High steam pressures, saturated steam, severe service, oil fed into steam line—Texaco Zenith Valve Oil.

Medium to high steam pressures, saturated steam, oil fed into steam line—Texaco Pinnacle Cylinder Oil.

Medium to high steam pressures, saturated steam, oil fed on valves or very close to throttle—Texaco Regal Cylinder Oil.

Low steam pressure, wet steam, oil fed into steam line—Texaco Draco Cylinder Oil.

Marine Engines—Texaco Pinnacle Mineral Cylinder Oil.

Ice & Refrigerating Plants—Texaco Vanguard Mineral Cylinder Oil.

General Service where mineral cylinder oil is required—Texaco Pinnacle Mineral Cylinder Oil.

STEAM TURBINE OIL FILTRATION

By Edwin M. May
Eastern Sales Manager, The Richardson-Phenix Co.

WHEN the predecessor of the modern turbo-generator began to make itself heard in the stationary power plant field twelve to fifteen years ago, the vertical shaft type was most generally used. This necessitated the use of the step bearing. In order to keep this properly lubricated a copious flow of oil was necessary and it was very important that all of this oil be kept clean all of the time. Various methods were then used for either continually filtering the oil through some sort of a makeshift filtering medium or arrangements were made so that the oil was taken out periodically, settled, and then used over again. The horizontal type of steam turbine became more successful shortly thereafter and we see the gradual displacement not only of the old vertical turbo-generators but also of the large Corliss and gas engines, and in fact, today in some cases, steam turbine generating sets are used in competition with hydro-electric units, so low is their cost of kilowatt output.

What does this mean? To the casual observer it means that a modern steam turbine has been perfected to the point where greater efficiencies than were ever thought of are now possible, but the engineer who looks into the question will realize that it means not only better design, but the perfection of detail and simplification of operation—both tending to lower the cost.

In a great many of the original horizontal steam turbine sets, the quantities of oil in the circulating system were so small that the general practice was to put in charges of new oil when this oil became "worn out" and use the old oil for auxiliaries. As the speeds became greater it was found necessary to have a more comprehensive lubricating system, and in the horizontal turbine, as now designed, large quantities of oil are circulated at a high rate of speed through the piping and to the bearings. None of the turbine manufacturers, however, include in the circulating system furnished with the turbine a filtering system, their system usually consisting of a strainer placed in the drain line, a pump, a cooler, and distributing piping.

As stated above, while it is true that the quantities of oil in the circulating systems of the turbine have been greatly increased over what they formerly were, still the amount of oil involved is so small in comparison to the more difficult conditions which are encountered, that it is quite essential to purify it. This oil travels at a very great rate of speed through the circulating system and is circulated anywhere

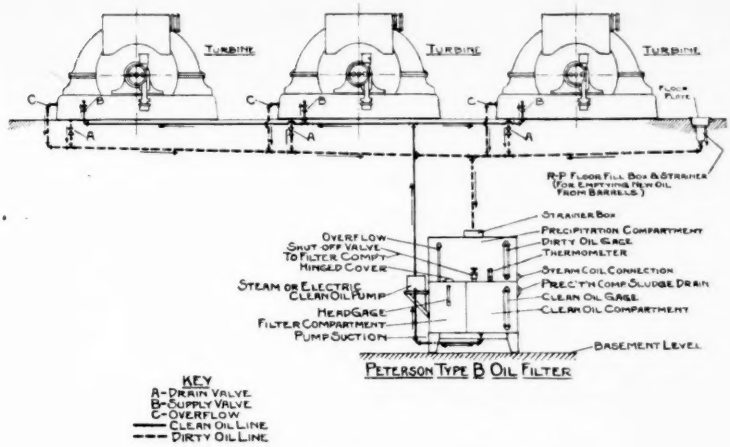

Figure 1—Batch System of Filtration

from once to three times every 10 minutes, depending upon the make and size of the turbine. The result is that a partial breaking down of the oil occurs, due to oxidation products being formed on account of the high temperatures encountered in the bearings. These oxidation products settle out, together with any water leakages and fine particles of grit and dirt, on the coolest part of the system. This, of course, is the cooler tubes. The action is cumulative and the walls of the tubes become thicker and thicker, thus not only hindering the flow of oil through them, but increasing the thickness of the walls and consequently decreasing the efficiency of the cooler.

Filtration of oil is therefore not only resorted to in order to save the oil and use it over again, but to keep this foreign matter, or "muck" as it is called, out of the cooler and permit the latter to do its full share of the work and also to prevent lubrication of the bearings by a mixture of water and oil instead of clean oil.

The continuous system of filtration is practically out of the question as the amount of oil involved is so large that the cost of the filtering equipment would be prohibitive, and furthermore it is unnecessary. There are two types of turbine oil filtering systems in general use, the first is known as the "batch filtration system" and the second, the "partial filtration system."

The batch system of filtration is shown in Figure 1 and is most generally employed where there are two or more units in the plant, as it is necessary to shut down the unit from which the oil is to be drawn off and filtered. The batch type filter consists of three compartments and is placed below the turbine room floor so that the oil from any particular turbine may be drained to it by gravity. The upper compartment of the filter is equipped with heating coils and is so arranged that the entire charge of oil from any one turbine may be emptied into it and heated to a temperature of from 145° to 160° so that the viscosity is reduced and the heavy particles of dirt and the water and foreign matter are precipitated out. A suitable draw-off for these foreign matters is provided and then the oil is per-

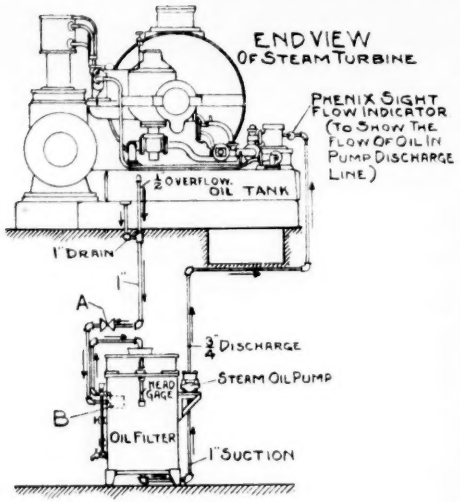

Figure 2—Partial Filtration System

mitted to flow by gravity over into the filtering compartment in the front part of the filter. Here it passes through the filtering medium and overflows into the clean oil storage chamber, ready to be used over again.

A few words might not go amiss at this point in regard to the type of oil filter to be selected, and for the reader's guidance we might mention the requirements necessary for a proper filter for handling steam turbine oil. They are as follows:

(1) Means for reducing the viscosity of the entering oil.
(2) Ample precipitation area.
(3) Water removal facilities.
(4) Vertical cloth system of dry filtration.
(5) Multiple unit design to facilitate changes of filter cloth without interruption to continuous filtration.

Referring to the above five important points it is obvious that where foreign matter has been developed and water is encountered it is necessary to reduce the viscosity of the oil. Oil used in steam turbines is a pure mineral oil and there is no saponification, so that it should be a very simple matter to precipitate water and foreign matter, provided, of course, heat can be applied and ample precipitation surface is furnished in the filter.

In the batch type of filter, water is drained off by hand, but in the type used for continuous or partial filtration, as described below, the water is automatically ejected.

There have been all kinds of filtering media used, varying all the way from bone-black to waste, excelsior or small pebbles, but most filters in modern power plants are of the cloth type. In fact, in 1826, when oil was first refined by Benjamin Silliman, Sr., as he took it from the surface of creeks in Allegheny County, New York, he passed it through flannel cloths.

With the use of cloth as a filtering medium, the filter should be so designed that the cloth will not be in a horizontal position as this would permit the foreign matter to lay on it and "cake," greatly reducing its filtering capacity and making it necessary to have more filtering surface than is actually needed besides increasing the difficulty of cleaning. The ideal way of filtering, as in the Peterson power plant filter, is to place the cloth in a vertical position without plaits or folds so that the accumulated dirt which forms on the outside of the filter unit has a tendency to slide down and not retard the flow of oil through the cloth. It is furthermore necessary to have more than one filter unit and these should be so arranged that any one of them may be withdrawn for changing the cloths without in any way interrupting the continuous flow of oil through the filter. The filter unit is a steel frame 1" wide and made in sizes from 12" x 12" up to 18" x 36".

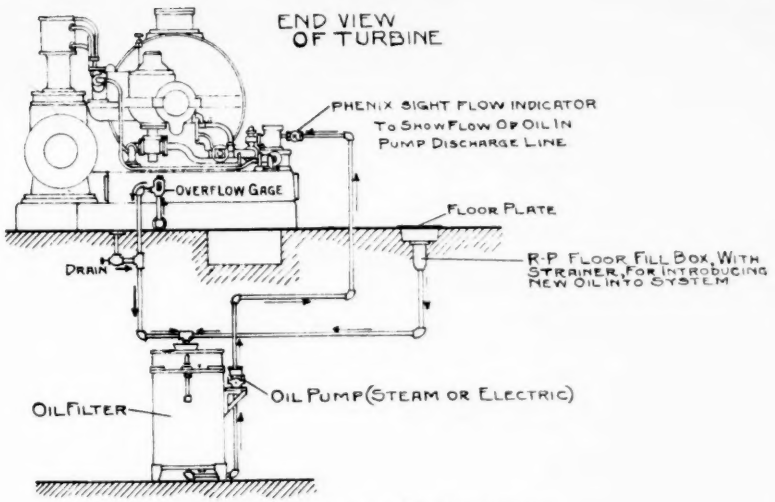

Figure 3—Another Partial Filtration System

The cloth bag covers the outside of the frame, which latter has a wire mesh on both sides to keep the cloth from collapsing, as filtration is caused by the oil passing from the outside through to the inside of the unit.

In the partial filtration system of handling turbine oil, part of the oil is bled from the lowest part of the circulating system, which is of course the dirtiest part, passed through the filter, and then pumped back into the system. There are two ways of doing this, as shown in Figure 2 and Figure 3.

Figure 2 shows such a system involving the use of valves, and its operation is as follows:

Valve "A" is opened so that the flow every hour about equals the amount contained in the turbine oil circulating system. This passes through float control valve "B" before it enters the precipitation compartment of the filter. Valve "B" is regulated by the height of oil in this clean oil compartment of the filter and its function is to prevent draining the turbine oil circulating system in the event of the failure of the oil pump. This pump may be of the steam or electric type and is either controlled by a governor in the clean oil compartment or set to operate at a certain rate of speed, to pump clean oil back into the turbine oil tank.

The system as shown in Figure 3 eliminates the use of valves and operates on the displacement principle. An overflow gauge is placed on the turbine oil tank, having its point of overflow at the level at which it is desired to keep the oil in the tank. The oil that passes to the filter below is taken from the lowest part of the oil tank via this overflow gauge, is purified, and then pumped back into the tank, the clean oil displacing the dirty oil through the overflow gauge. It is obvious that the capacity of the pump is the factor which determines the rate of change of oil. It is, of course, necessary to have the filter of ample size to take care of this capacity.

The type of filter usually found in the partial filtration system differs from the batch type of filter in that means are provided for the precipitation process to take place as

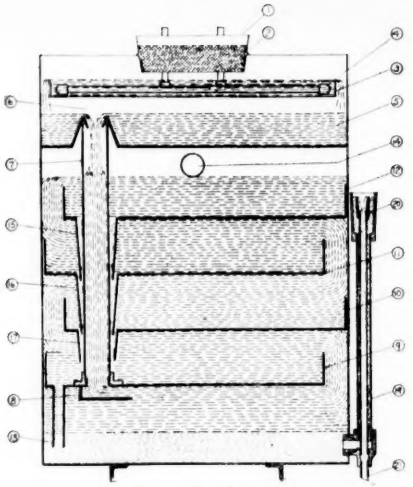

Figure 4—Precipitation Compartment

the oil passes through the filter. The oil after passing over the heating coils flows down through the tube to the bottom of the trays in the rear of the filter. It then takes a path as indicated on the diagram in Figure 4, moving very slowly and finally reaching the tube or overflow point and passing into the filtering compartment. The oil moves over these trays at a very low velocity, 7/10 ft. per minute, at normal rated capacity of the filter, and the heavy particles of "muck" and dirt and also the water settle to the bottom of these trays. As the water is settled out of the oil it takes a course at right angles to the flow of oil and the movement of oil offers no resistance to the precipitation process. Any solid matter which is precipitated collects in the bottom of the trays, and as the oil flows over them at such a low velocity, and inasmuch as the sediment is not in the direct course of the oil, there is no danger of its being picked up again. These trays are quite deep and hold a large quantity of sediment, thus rendering frequent cleaning unnecessary. The water is trapped out through the automatic water ejector on the side of the filter. The clean oil compartment is composed of a suitable number of filtering units which are similar to the ones used in the batch type of filter.

Both the batch type and the partial filtration systems are good systems to use, but the tendency seems to be more toward the partial system of filtration as its operation is entirely automatic and the oil in the turbine circulating system is always clean. In the batch type of filter the oil is circulated in the turbine oil until it reaches the point where it is in bad condition and is then purified. This means that the average amount of foreign matter and water in the oil of a batch operated filtration system is higher than in the partial filtration system. Heretofore in plants having only one or two turbines the partial system was used and where there were more than two turbines, the batch system. To show the way opinion has changed, the writer knows of one plant in New England which now consists of two 15,000 kw turbo-generators, each using a partial filtration system, and which will ultimately have eight more units of similar size, each of these to be equipped with a partial filtration system, as they are installed.

Where only one turbine is operated the first cost of a batch filtration system would be higher, otherwise the first cost of the partial filtration system is greater. In a great many instances this has been the deciding factor. However, most engineers these days look more towards the future and, although the partial filtration system might cost a little more, it pays for itself sooner, in that it *always* keeps *all* of the oil in the turbine circulating system clean.